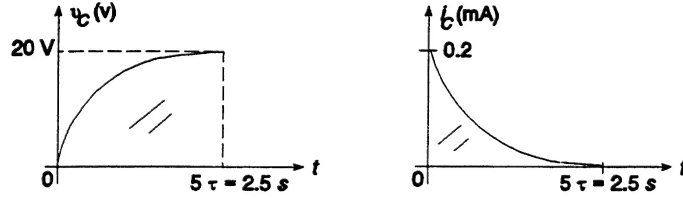


CHAPTER 10 (Odd)

1. $\mathcal{E} = k \frac{Q_1}{r^2} = \frac{(9 \times 10^9)(4 \mu\text{C})}{(2 \text{ m})^2} = 9 \times 10^3 \text{ N/C}$
3. $C = \frac{Q}{V} = \frac{1400 \mu\text{C}}{20 \text{ V}} = 70 \mu\text{F}$
5. $\mathcal{E} = \frac{V}{d} = \frac{100 \text{ mV}}{2 \text{ mm}} = 50 \text{ V/m}$
7. $V = \frac{Q}{C} = \frac{160 \mu\text{C}}{4 \mu\text{F}} = 40 \text{ V}$
 $\mathcal{E} = \frac{V}{d} = \frac{40 \text{ V}}{5 \text{ mm}} = 8 \times 10^3 \text{ V/m}$
9. $C = 8.85 \times 10^{-12} \epsilon_r \frac{A}{d} = 8.85 \times 10^{-12} (2.5) \frac{(75 \times 10^{-3} \text{ m}^2)}{1.77 \text{ mm}} = 937.5 \text{ pF}$
11. $C = \epsilon_r C_o \Rightarrow \epsilon_r = \frac{C}{C_o} = \frac{0.006 \mu\text{F}}{1200 \text{ pF}} = 5 \text{ (mica)}$
13. a. $\mathcal{E} = \frac{V}{d} = \frac{200 \text{ V}}{0.2 \text{ mm}} = 10^6 \text{ V/m}$
 b. $Q = \epsilon \mathcal{E} A = \epsilon_r \epsilon_o \mathcal{E} A = (7)(8.85 \times 10^{-12})(10^6 \text{ V/m})(0.08 \text{ m}^2) = 4.96 \mu\text{C}$
 c. $C = \frac{Q}{V} = \frac{4.96 \mu\text{C}}{200 \text{ V}} = 0.0248 \mu\text{F}$
15. $d = \frac{8.85 \times 10^{-12} \epsilon_r A}{C} = \frac{(8.85 \times 10^{-12})(5)(0.02 \text{ m}^2)}{0.006 \mu\text{F}} = 0.1475 \text{ mm} = 147.5 \mu\text{m}$
 $d = 0.1475 \text{ mm} \left[\frac{10^{-3} \text{ m}}{1 \text{ mm}} \right] \left[\frac{39.37 \text{ in.}}{1 \text{ m}} \right] \left[\frac{1000 \text{ mils}}{1 \text{ in.}} \right] = 5.807 \text{ mils}$
 $5.807 \text{ mils} \left[\frac{5000 \text{ V}}{\text{mil}} \right] = 29,035 \text{ V}$
17. a. $\tau = RC = (10^5 \Omega)(5 \mu\text{F}) = 0.5 \text{ s}$
 b. $v_C = E(1 - e^{-t/\tau}) = 20(1 - e^{-t/0.5})$
 c. $1\tau = 0.632(20 \text{ V}) = 12.64 \text{ V}, 3\tau = 0.95(20 \text{ V}) = 19 \text{ V}$
 $5\tau = 0.993(20 \text{ V}) = 19.87 \text{ V}$
 d. $i_C = \frac{20\text{V}}{100 \text{ k}\Omega} e^{-t/\tau} = 0.2 \times 10^{-3} e^{-t/0.5}$
 $v_R = E e^{-t/\tau} = 20 e^{-t/0.5}$

e.



19. a. $\tau = RC = (2.2 \text{ k}\Omega + 3.3 \text{ k}\Omega)1 \text{ }\mu\text{F} = (5.5 \text{ k}\Omega)(1 \text{ }\mu\text{F}) = 5.5 \text{ ms}$

b. $v_C = E(1 - e^{-t/\tau}) = 100(1 - e^{-t/5.5 \times 10^{-3}})$

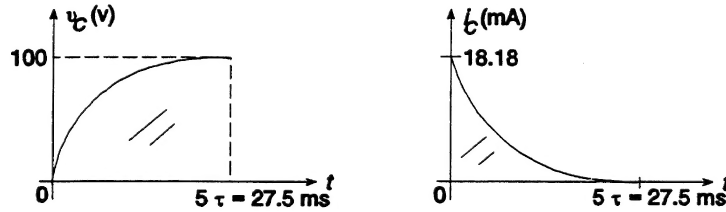
c. $1\tau = 63.21 \text{ V}, 3\tau = 95.02 \text{ V}, 5\tau = 99.33 \text{ V}$

d. $i_C = \frac{E}{R_T} e^{-t/\tau} = \frac{100 \text{ V}}{5.5 \text{ k}\Omega} e^{-t/\tau} = 18.18 \times 10^{-3} e^{-t/5.5 \times 10^{-3}}$

$$V_{R_2} = \frac{3.3 \text{ k}\Omega(100 \text{ V})}{3.3 \text{ k}\Omega + 2.2 \text{ k}\Omega} = 60 \text{ V}$$

$$v_R = v_{R_2} = 60 e^{-t/5.5 \times 10^{-3}}$$

e.



21. a. $\tau = RC = (2 \text{ k}\Omega + 3 \text{ k}\Omega)2 \text{ }\mu\text{F} = (5 \text{ k}\Omega)(2 \text{ }\mu\text{F}) = 10 \text{ ms}$

b. $v_C = 50(1 - e^{-t/10 \times 10^{-3}})$

c. $i_C = \frac{50 \text{ V}}{5 \text{ k}\Omega} e^{-t/\tau} = 10 \times 10^{-3} e^{-t/10 \times 10^{-3}}$

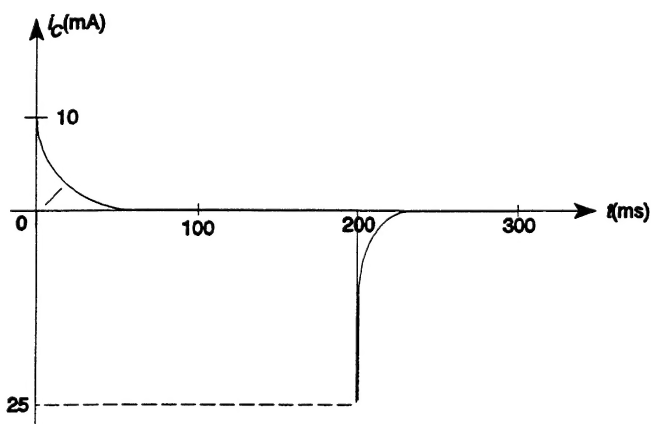
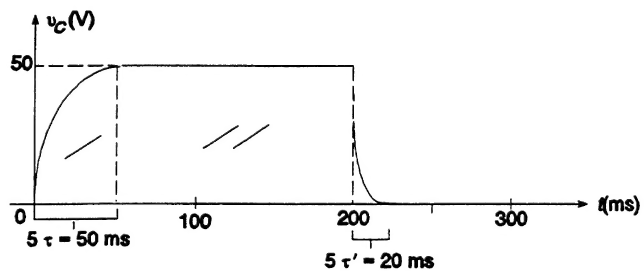
d. $t = 100 \text{ ms:}$ $v_C = 50(1 - e^{-t/\tau}) = 50(1 - e^{-10}) = 49.997 \text{ V} \cong 50 \text{ V}$
 $i_C \cong 0 \text{ mA}$

e. $\tau' = R_2 C = (2 \text{ k}\Omega)(2 \text{ }\mu\text{F}) = 4 \text{ ms}$

$$v_C = 50 e^{-t/\tau'} = 50 e^{-t/4 \times 10^{-3}}$$

$$i_C = \frac{50 \text{ V}}{2 \text{ k}\Omega} e^{-t/\tau'} = 25 \times 10^{-3} e^{-t/4 \times 10^{-3}}$$

f.



23. a. $\tau = R_1 C = (10^5 \Omega)(10 \text{ pF}) = 1 \mu\text{s}$

$$v_C = 80(1 - e^{-t/1 \times 10^{-6}})$$

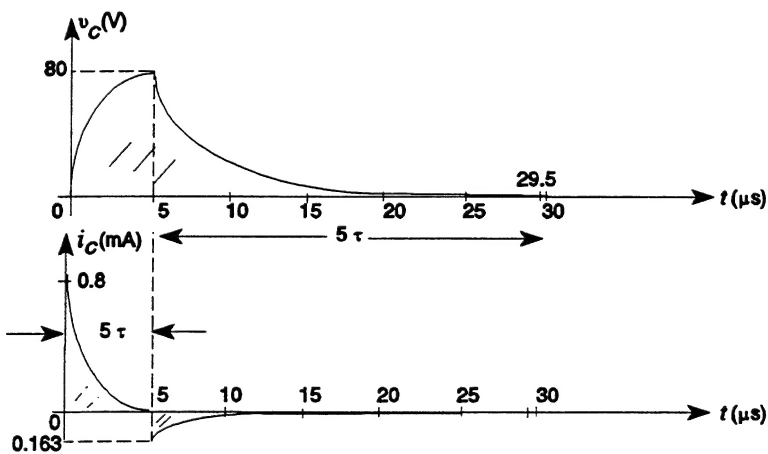
b. $i_C = \frac{80 \text{ V}}{100 \text{ k}\Omega} e^{-t/\tau} = 0.8 \times 10^{-3} e^{-t/1 \times 10^{-6}}$

c. $\tau' = R' C = (490 \text{ k}\Omega)(10 \text{ pF}) = 4.9 \mu\text{s}$

$$v_C = 80 e^{-t/\tau'} = 80 e^{-t/4.9 \times 10^{-6}}$$

$$i_C = \frac{80 \text{ V}}{490 \text{ k}\Omega} e^{-t/\tau'} = 0.163 \times 10^{-3} e^{-t/4.9 \times 10^{-6}}$$

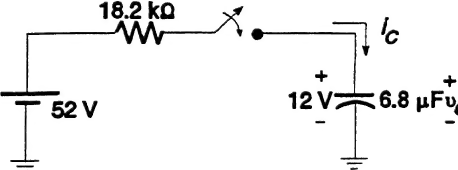
d.



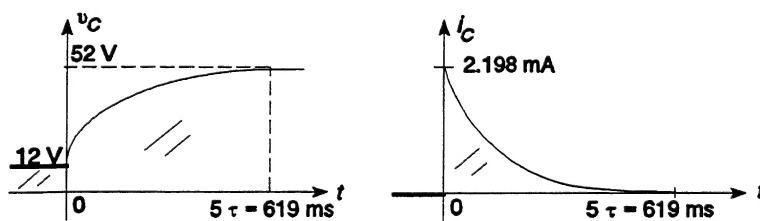
25. a. $\tau = RC = (2 \text{ m}\Omega)(1000 \text{ }\mu\text{F}) = 2 \text{ }\mu\text{s}$
 $5\tau = 10 \text{ }\mu\text{s}$

b. $I_m = \frac{V}{R} = \frac{6 \text{ V}}{2 \text{ m}\Omega} = 3 \text{ kA}$

c. yes

27. a. 
 $\tau = RC = (18.2 \text{ k}\Omega)(6.8 \text{ }\mu\text{F}) = 123.8 \text{ ms}$
 $v_C = V_f + (V_i - V_f)e^{-t/\tau}$
 $= 52 \text{ V} + (12 \text{ V} - 52 \text{ V})e^{-t/123.8 \text{ ms}}$
 $v_C = 52 \text{ V} - 40 \text{ V}e^{-t/123.8 \text{ ms}}$
 $v_R(0+) = 52 \text{ V} - 12 \text{ V} = 40 \text{ V}$
 $i_C = \frac{40 \text{ V}}{18.2 \text{ k}\Omega}e^{-t/123.8 \text{ ms}}$
 $= 2.198 \text{ mA}e^{-t/123.8 \text{ ms}}$

b.



29. $i_C = \frac{1}{2} \frac{E}{R} = \frac{E}{R}e^{-t/\tau}$
 $\frac{1}{2} I_m = I_m$
 $\frac{1}{2} = e^{-t/\tau} \Rightarrow \log_e \frac{1}{2} = -t/\tau \Rightarrow t = -\tau \log_e \frac{1}{2}$
 $t = -2 \times 10^{-6} \log_e \frac{1}{2}$
 $= -(2 \times 10^{-6})(-0.693)$
 $= 1.386 \text{ }\mu\text{s}$

31. Eq. 10.23:

$$t = -\tau \log_e \left[1 - \frac{v_C}{E} \right]$$

$$10 \text{ s} = -\tau \log_e \left[1 - \frac{12 \text{ V}}{20 \text{ V}} \right]$$

$$\underbrace{\left[1 - \frac{12 \text{ V}}{20 \text{ V}} \right]}_{.04}$$

$$\underbrace{\log_e .04}_{-0.9163}$$

$$\tau = \frac{10 \text{ s}}{0.9163} = 10.913 \text{ s}$$

$$\tau = RC \Rightarrow R = \frac{\tau}{C} = \frac{10.913 \text{ s}}{200 \text{ }\mu\text{F}} = 54.567 \text{ k}\Omega$$

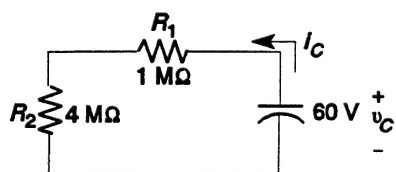
33. a. $\tau = RC = (1 \text{ M}\Omega)(0.2 \text{ }\mu\text{F}) = 0.2 \text{ s}$
 $v_C = 60(1 - e^{-t/0.2\text{s}})$
 $i_C = \frac{E}{R}e^{-t/\tau} = \frac{60 \text{ V}}{1 \text{ M}\Omega}e^{-t/0.2\text{s}} = 60 \times 10^{-6}e^{-t/0.2\text{s}}$
 $v_{R_1} = Ee^{-t/\tau} = 60e^{-t/0.2\text{s}}$

$v_C: 0.5 \text{ s} = 55.07 \text{ V}$
 $1 \text{ s} = 59.576 \text{ V}$

$i_C: 0.5 \text{ s} = 4.93 \text{ }\mu\text{A}$
 $1 \text{ s} = 0.404 \text{ }\mu\text{A}$

$v_{R_1}: 0.5 \text{ s} = 4.93 \text{ V}$
 $1 \text{ s} = 0.404 \text{ V}$

b.



$\tau' = RC = (1 \text{ M}\Omega + 4 \text{ M}\Omega)(0.2 \text{ }\mu\text{F})$
 $= (5 \text{ M}\Omega)(0.2 \text{ }\mu\text{F})$
 $= 1 \text{ s}$

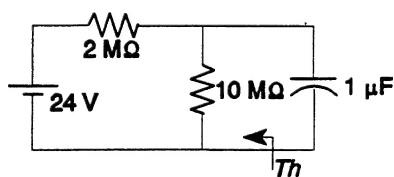
$i_C = \frac{60 \text{ V}}{5 \text{ M}\Omega}e^{-t} = 12 \times 10^{-6}e^{-t}$

$8 \times 10^{-6} = 12 \times 10^{-6}e^{-t}$
 $0.667 = e^{-t}$
 $\log_e 0.667 = -t$
 $-0.405 = -t$
 $t = 0.405 \text{ s}$

$v_C = 60e^{-t/\tau'}$
 $10 = 60e^{-t}$
 $0.1667 = e^{-t}$
 $\log_e 0.1667 = -t$
 $-1.792 = -t$
 $t = 1.792 \text{ s}$

Longer = $1.792 \text{ s} - 0.405 \text{ s} = 1.387 \text{ s}$

35. a.



$R_{Th} = 2 \text{ M}\Omega \parallel 10 \text{ M}\Omega = 1.667 \text{ M}\Omega$

$E_{Th} = \frac{10 \text{ M}\Omega(24 \text{ V})}{10 \text{ M}\Omega + 2 \text{ M}\Omega} = 20 \text{ V}$

$v_C = E_{Th}(1 - e^{-t/\tau})$
 $= 20 \text{ V}(1 - e^{-4t/\tau})$
 $= 20 \text{ V}(1 - e^{-4})$
 $= 20 \text{ V}(1 - 0.0183)$
 $= 19.634 \text{ V}$

$$\tau = R_{Th}C = (1.667 \text{ M}\Omega)(1 \text{ }\mu\text{F}) = 1.667 \text{ s}$$

$$i_C = \frac{E}{R} e^{-t/\tau}$$

$$3 \text{ }\mu\text{A} = \frac{20 \text{ V}}{1.667 \text{ M}\Omega} e^{-t/1.667 \text{ s}}$$

$$0.25 = e^{-t/1.667 \text{ s}}$$

$$\log_e 0.25 = -t/1.667 \text{ s}$$

$$t = -(1.667 \text{ s})(-1.386) \\ = 2.31 \text{ s}$$

c.

$$v_{\text{meter}} = v_C$$

$$v_C = E_{Th}(1 - e^{-t/\tau})$$

$$10 \text{ V} = 20 \text{ V}(1 - e^{-t/1.667 \text{ s}})$$

$$0.5 = 1 - e^{-t/1.667 \text{ s}}$$

$$-0.5 = -e^{-t/1.667 \text{ s}}$$

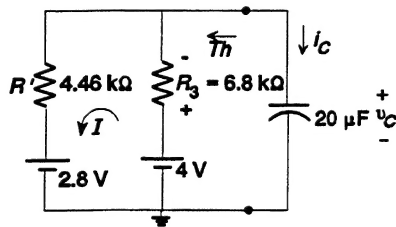
$$\log_e 0.5 = -t/1.667 \text{ s}$$

$$t = -(1.667 \text{ s})(-0.693) \\ = 1.155 \text{ s}$$

37. a. Source conversion:

$$E = IR_1 = (5 \text{ mA})(0.56 \text{ k}\Omega) = 2.8 \text{ V}$$

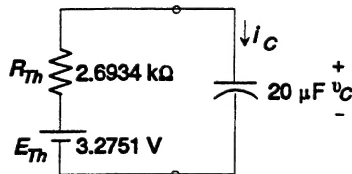
$$R' = R_1 + R_2 = 0.56 \text{ k}\Omega + 3.9 \text{ k}\Omega = 4.46 \text{ k}\Omega$$



$$R_{Th} = 4.46 \text{ k}\Omega \parallel 6.8 \text{ k}\Omega = 2.6934 \text{ k}\Omega$$

$$I = \frac{4 \text{ V} - 2.8 \text{ V}}{6.8 \text{ k}\Omega + 4.46 \text{ k}\Omega} = \frac{1.2 \text{ V}}{11.26 \text{ k}\Omega} = 0.1066 \text{ mA}$$

$$E_{Th} = 4 \text{ V} - (0.1066 \text{ mA})(6.8 \text{ k}\Omega) \\ = 4 \text{ V} - 0.7249 \text{ V} \\ = 3.2751 \text{ V}$$



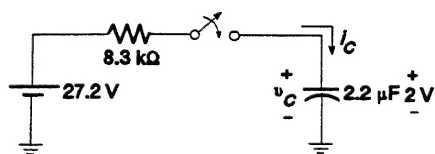
$$v_C = 3.2751(1 - e^{-t/\tau})$$

$$\tau = RC = (2.6934 \text{ k}\Omega)(20 \text{ }\mu\text{F}) \\ = 53.87 \text{ ms}$$

$$v_C = 3.2751(1 - e^{-t/53.87 \text{ ms}})$$

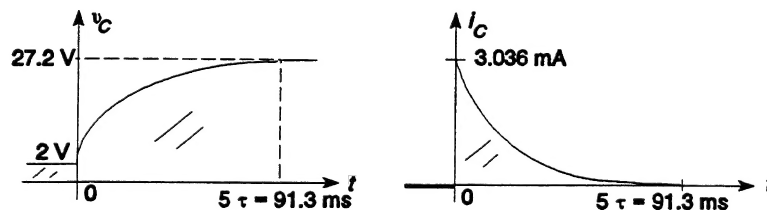
$$i_C = \frac{3.2751 \text{ V}}{2.6934 \text{ k}\Omega} e^{-t/\tau} \\ = 1.216 \times 10^{-3} e^{-t/53.87 \text{ ms}}$$

39. a. Source conversion:



$$\begin{aligned}\tau &= RC = (8.3 \text{ k}\Omega)(2.2 \text{ }\mu\text{F}) = 18.26 \text{ ms} \\ v_C &= V_f + (V_i - V_f)e^{-t/\tau} \\ &= 27.2 \text{ V} + (2 \text{ V} - 27.2 \text{ V})e^{-t/18.26 \text{ ms}} \\ v_C &= 27.2 \text{ V} - 25.2 \text{ V}e^{-t/18.26 \text{ ms}} \\ v_R(0+) &= 27.2 \text{ V} - 2 \text{ V} = 25.2 \text{ V} \\ i_C &= \frac{25.2 \text{ V}}{8.3 \text{ k}\Omega}e^{-t/18.26 \text{ ms}} \\ i_C &= 3.036 \text{ mA}e^{-t/18.26 \text{ ms}}\end{aligned}$$

b.



41. $i_C = C \frac{\Delta V}{\Delta t}$: $i_C = 0.06 \times 10^{-6} \frac{\Delta V}{\Delta t}$

0 – 4 ms: $i_C = 0.06 \times 10^{-6} \left[\frac{20 \text{ V}}{4 \text{ ms}} \right] = 0.3 \text{ mA}$

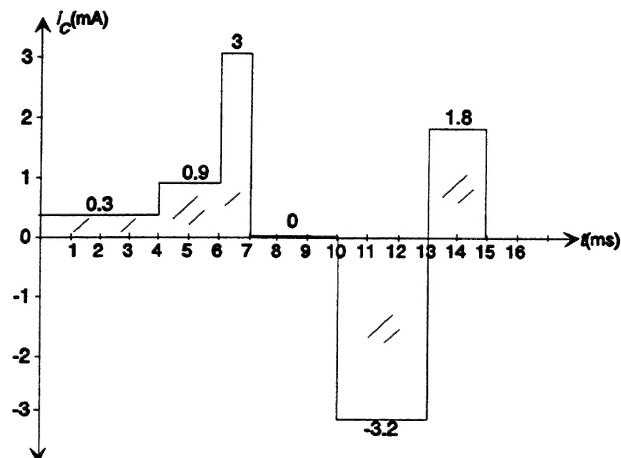
4 – 6 ms: $i_C = 0.06 \times 10^{-6} \left[\frac{30 \text{ V}}{2 \text{ ms}} \right] = 0.9 \text{ mA}$

6 – 7 ms: $i_C = 0.06 \times 10^{-6} \left[\frac{50 \text{ V}}{1 \text{ ms}} \right] = 3 \text{ mA}$

7 – 10 ms: $i_C = 0 \text{ mA}$

10 – 13 ms: $i_C = -0.06 \times 10^{-6} \left[\frac{160 \text{ V}}{3 \text{ ms}} \right] = -3.2 \text{ mA}$

13 – 15 ms: $i_C = 0.06 \times 10^{-6} \left[\frac{60 \text{ V}}{2 \text{ ms}} \right] = 1.8 \text{ mA}$



$$43. \quad i_C = C \frac{\Delta V_C}{\Delta t} \Rightarrow \Delta V_C = \frac{\Delta t}{C} (i_C)$$

$$0 - 4 \text{ ms: } i_C = 0 \text{ mA}, \Delta V_C = 0 \text{ V}$$

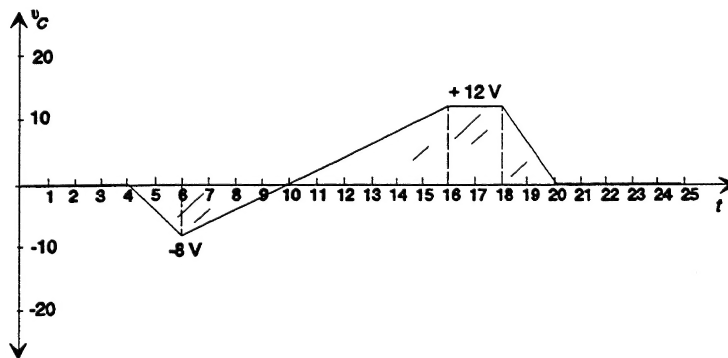
$$4 - 6 \text{ ms: } i_C = -80 \text{ mA}, \Delta V_C = \frac{(2 \text{ ms})}{20 \mu\text{F}} (-80 \text{ mA}) = -8 \text{ V}$$

$$6 - 16 \text{ ms: } i_C = +40 \text{ mA}, \Delta V_C = \frac{(10 \text{ ms})}{20 \mu\text{F}} (40 \text{ mA}) = +20 \text{ V}$$

$$16 - 18 \text{ ms: } i_C = 0 \text{ mA}, \Delta V_C = 0 \text{ V}$$

$$18 - 20 \text{ ms: } i_C = -120 \text{ mA}, \Delta V_C = \frac{(2 \text{ ms})}{20 \mu\text{F}} (-120 \text{ mA}) = -12 \text{ V}$$

$$20 - 25 \text{ ms: } i_C = 0 \text{ mA}, \Delta V_C = 0 \text{ V}$$



$$45. \quad V_1 = 10 \text{ V}, Q_1 = C_1 V_1 = (6 \mu\text{F})(10 \text{ V}) = 60 \mu\text{C}$$

$$Q_2 = Q_3 = C_T V = (4 \mu\text{F})(10 \text{ V}) = 40 \mu\text{C}$$

$$V_2 = Q_2 / C_2 = 40 \mu\text{C} / 6 \mu\text{F} = 6.67 \text{ V}$$

$$V_3 = Q_3 / C_3 = 40 \mu\text{C} / 12 \mu\text{F} = 3.33 \text{ V}$$

$$47. \quad \text{a. } C_T = \frac{(8 \mu\text{F})(24 \mu\text{F})}{8 \mu\text{F} + 24 \mu\text{F}} = 6 \mu\text{F}$$

$$\tau = RC = (20 \text{ k}\Omega)(6 \mu\text{F}) = 120 \text{ ms}$$

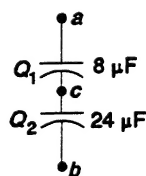
$$v_{ab} = v_{C_T} = 100(1 - e^{-t/120\text{ms}})$$

$$\text{At } t = 100 \text{ ms}$$

$$v_{ab} = 100 \left[1 - e^{-\frac{100\text{ms}}{120\text{ms}}} \right] = 100(1 - e^{-0.833})$$

$$= 100(.5654) = 56.54 \text{ V}$$

b, c.



$$Q_1 = Q_2 = C_T V_{ab} = (6 \mu\text{F})(56.54 \text{ V}) = 339.24 \mu\text{C}$$

$$C_1 V_1 = C_2 V_2$$

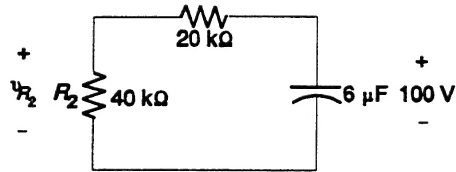
$$8 \mu\text{F } V_{ac} = 24 \mu\text{F } V_{cb} = 339.24 \mu\text{C}$$

$$\text{and } V_{ac} = \frac{339.24 \mu\text{C}}{8 \mu\text{F}} = 42.405 \text{ V}$$

$$V_{cb} = \frac{339.24 \mu\text{C}}{24 \mu\text{F}} = 14.135 \text{ V}$$

d. $V_{da} = E - V_{ab} = 100 \text{ V} - 56.54 \text{ V} = 43.46 \text{ V}$

e.



$$i_C = \frac{E}{R_T} e^{-t/\tau}, \tau = RC = (60 \text{ k}\Omega)(6 \mu\text{F}) = 360 \text{ ms}$$

$$i_C = \frac{100 \text{ V}}{60 \text{ k}\Omega} e^{-t/360\text{ms}} = 1.667 \times 10^{-3} e^{-t/360\text{ms}}$$

$$v_{R_2} = i_C R_2 = (1.667 \text{ mA})(40 \text{ k}\Omega) e^{-t/360\text{ms}}$$

$$= 66.67 e^{-t/360\text{ms}}$$

$$20 = 66.67 e^{-t/360\text{ms}} \Rightarrow 0.3 = e^{-t/360\text{ms}}$$

$$\log_e 0.3 = -t/360 \text{ ms}$$

$$-1.204 = -t/360 \text{ ms}$$

$$t = 1.204(360 \text{ ms})$$

$$= 433.44 \text{ ms}$$

49. $W_C = \frac{1}{2} CV^2 = \frac{1}{2} (120 \text{ pF})(12 \text{ V})^2 = 8,640 \text{ pJ}$

51. a. $W_C = \frac{1}{2} CV^2 = \frac{1}{2} (1000 \mu\text{F})(100 \text{ V})^2 = 5 \text{ J}$

b. $Q = CV = (1000 \mu\text{C})(100 \text{ V}) = 0.1 \text{ C}$

c. $I = Q/t = 0.1 \text{ C}/(1/2000) = 200 \text{ A}$

d. $P = V_{av} I_{av} = W/t = 5 \text{ J}/(1/2000 \text{ s}) = 10,000 \text{ W}$

e. $t = Q/I = 0.1 \text{ C}/10 \text{ mA} = 10 \text{ s}$

CHAPTER 10 (Even)

$$2. \quad \mathcal{E} = \frac{kQ}{r^2} \Rightarrow r = \sqrt{\frac{kQ}{\mathcal{E}}} = \sqrt{\frac{(9 \times 10^9)(0.064 \mu\text{C})}{36 \text{ N/C}}} = 4 \text{ m}$$

$$4. \quad Q = CV = (0.05 \mu\text{F})(45 \text{ V}) = 2.25 \mu\text{C}$$

$$6. \quad d = 4 \text{ mils} \left[\frac{10^{-3} \text{ in.}}{1 \text{ mil}} \right] \left[\frac{1 \text{ m}}{39.37 \text{ in.}} \right] = 0.102 \text{ mm}$$

$$\mathcal{E} = \frac{V}{d} = \frac{100 \text{ mV}}{0.102 \text{ mm}} = 980.39 \text{ V/m}$$

$$8. \quad C = 8.85 \times 10^{-12} \epsilon_r \frac{A}{d} = 8.85 \times 10^{-12} (1) \frac{(0.075 \text{ m}^2)}{1.77 \text{ mm}} = 375 \text{ pF}$$

$$10. \quad C = 8.85 \times 10^{-12} \epsilon_r \frac{A}{d} \Rightarrow d = \frac{8.85 \times 10^{-12} (4) (0.09 \text{ m}^2)}{2 \mu\text{F}} = 1.593 \mu\text{m}$$

$$12. \quad \text{a.} \quad C = 8.85 \times 10^{-12} (1) \frac{(0.08 \text{ m}^2)}{0.2 \text{ mm}} = 3.54 \text{ nF}$$

$$\text{b.} \quad \mathcal{E} = \frac{V}{d} = \frac{200 \text{ V}}{0.2 \text{ mm}} = 10^6 \text{ V/m}$$

$$\text{c.} \quad Q = CV = (3.54 \text{ nF})(200 \text{ V}) = 0.708 \mu\text{C}$$

$$14. \quad \#12: 0.2 \times 10^{-3} \text{ in} \left[\frac{39.37 \text{ in.}}{1 \text{ in.}} \right] \left[\frac{1 \text{ mil}}{10^{-3} \text{ in.}} \right] = 7.874 \text{ mils}$$

$$\frac{75 \text{ V}}{\text{mil}} [7.874 \text{ mils}] = 590.55 \text{ V}$$

$$\#13: \frac{400 \text{ V}}{\text{mil}} [7.874 \text{ mils}] = 3,149.60 \text{ V}$$

$$16. \quad \text{mica: } \frac{1250 \text{ V}}{5000 \text{ V}} = 1250 \mathcal{N} \left[\frac{\text{mil}}{5000 \mathcal{N}} \right] = 0.25 \text{ mils}$$

$$18. \quad \text{a.} \quad \tau = RC = (10^6 \Omega)(5 \mu\text{F}) = 5 \text{ s}$$

$$\text{b.} \quad v_C = E(1 - e^{-t/\tau}) = 20(1 - e^{-t/5})$$

$$\text{c.} \quad 1\tau = 12.64 \text{ V}, 3\tau = 19 \text{ V}, 5\tau = 19.87 \text{ V} \quad \text{d.} \quad i_C = \frac{20 \text{ V}}{1 \text{ M}\Omega} e^{-t/\tau} = 20 \times 10^{-6} e^{-t/5}$$

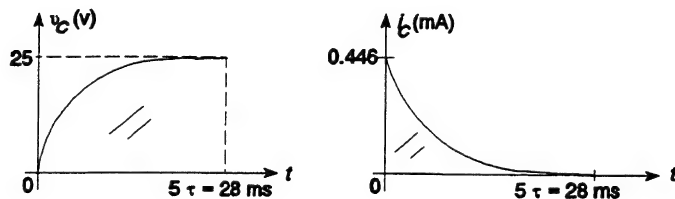
$$v_R = Ee^{-t/\tau} = 20e^{-t/5}$$

$$\text{e.} \quad \text{Same as 17 with } 5\tau = 25 \text{ s and } I_m = 20 \mu\text{A}$$

20. a. $\tau = RC = (56 \text{ k}\Omega)(0.1 \text{ }\mu\text{F}) = 5.6 \text{ ms}$ b. $v_C = E(1 - e^{-t/\tau}) = 25(1 - e^{-t/5.6\text{ms}})$

c. $i_C = \frac{E}{R}e^{-t/\tau} = \frac{25 \text{ V}}{56 \text{ k}\Omega}e^{-t/\tau} = 0.446 \times 10^{-3}e^{-t/5.6\text{ms}}$

d.



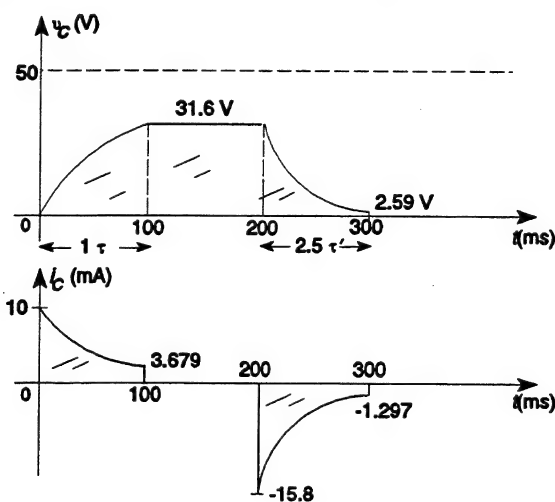
22. a. $\tau = RC = (5 \text{ k}\Omega)(20 \text{ }\mu\text{F}) = 100 \text{ ms}$ b. $v_C = 50(1 - e^{-t/100\text{ms}})$

c. $i_C = 10 \times 10^{-3}e^{-t/100\text{ms}}$

d. $v_C = 50(1 - e^{-1}) = 50(1 - 0.3679) = 50(0.6321) = 31.6 \text{ V}$
 $i_C = 10 \times 10^{-3}e^{-1} = 10 \times 10^{-3}(0.3679) = 3.679 \text{ mA}$

e. $\tau' = RC = (2 \text{ k}\Omega)(20 \text{ }\mu\text{F}) = 40 \text{ ms}$
 $v_C = 31.6e^{-t/40\text{ms}}$
 $i_C = \frac{31.6 \text{ V}}{2 \text{ k}\Omega}e^{-t/40\text{ms}} = 15.8 \times 10^{-3}e^{-t/40\text{ms}}$

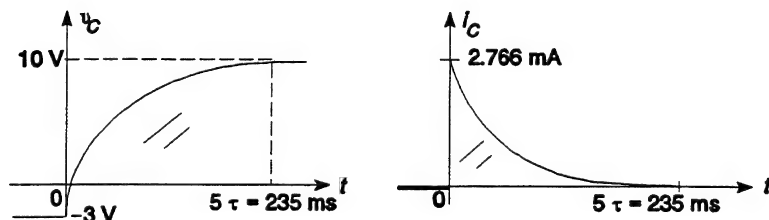
f. At $t = 2.5 \tau'$ (from 200 ms) \rightarrow at 300 ms
 $v_C = 31.6e^{-2.5} = 31.6(0.0821) = 2.59 \text{ V}$
 $i_C = 15.8 \times 10^{-3}e^{-2.5} = 1.297 \text{ mA}$



24. $\tau = RC = (2.2 \text{ k}\Omega)(2000 \text{ }\mu\text{F}) = 4.4 \text{ s}$
 $v_C = V_C e^{-t/\tau} = 40e^{-t/4.4}$
 $i_C = \frac{V_C}{R}e^{-t/\tau} = \frac{40 \text{ V}}{2.2 \text{ k}\Omega}e^{-t/4.4} = 18.18 \times 10^{-3}e^{-t/4.4}$
 $v_R = v_C = 40e^{-t/4.4}$

26. a. $\tau = RC = (4.7 \text{ k}\Omega)(10 \text{ }\mu\text{F}) = 47 \text{ ms}$
 $v_C = V_f + (V_i - V_f)e^{-t/\tau}$
 $= 10 \text{ V} + (-3 \text{ V} - 10 \text{ V})e^{-t/47 \text{ ms}}$
 $v_C = 10 \text{ V} - 13 \text{ V}e^{-t/47 \text{ ms}}$
 $v_R(0+) = 10 \text{ V} + 3 \text{ V} = 13 \text{ V}$
 $i_C = \frac{13 \text{ V}}{4.7 \text{ k}\Omega}e^{-t/47 \text{ ms}} = 2.766 \text{ mA}e^{-t/47 \text{ ms}}$

b.



28. a. $V_C = 8(1 - e^{-5\tau/\tau}) = 8(1 - e^{-5}) = 8(1 - 0.00674) = 7.946 \text{ V}$

b. $V_C = 8(1 - e^{-10}) = 8(1 - 0.0000454) = 7.996 \text{ V}$

c. $V_C = 8(1 - e^{-5 \times 10^{-6}/20 \times 10^{-6}}) = 8(1 - e^{-0.25}) = 8(1 - 0.7788) = 1.7696 \text{ V}$

30. $\tau = RC = (33 \text{ k}\Omega)(20 \text{ }\mu\text{F}) = 0.66 \text{ s}$
 $v_C = 12(1 - e^{-t/0.66})$
 $8 = 12(1 - e^{-t/0.66})$
 $8 = 12 - 12e^{-t/0.66}$
 $-4 = -12e^{-t/0.66}$
 $0.333 = e^{-t/0.66}$
 $\log_e 0.333 = -t/0.66$
 $-1.0996 = -t/0.66$
 $t = 1.0996(0.66) = 0.726 \text{ s}$

32. a. $\tau = (R_1 + R_2)C = (20 \text{ k}\Omega)(6 \text{ }\mu\text{F}) = 0.12 \text{ s}$
 $v_C = E(1 - e^{-t/\tau})$
 $60 \text{ V} = 80 \text{ V}(1 - e^{-t/0.12\text{s}})$
 $0.75 = 1 - e^{-t/0.12\text{s}}$
 $0.25 = e^{-t/0.12\text{s}}$
 $t = -(0.12 \text{ s})(-1.386)$
 $= 0.166 \text{ s}$

b. $i_C = \frac{E}{R}e^{-t/\tau}$
 $i_C = \frac{80 \text{ V}}{20 \text{ k}\Omega}e^{-\frac{0.166\text{s}}{0.12\text{s}}} = 4 \text{ mA} e^{-1.383}$
 $= (4 \text{ mA})(0.2508)$
 $\cong 1 \text{ mA}$

$$\begin{aligned}
 c. \quad i_s &= i_C = 4 \text{ mA } e^{-t/\tau} = 4 \text{ mA } e^{-2t/\tau} = 4 \text{ mA } e^{-2} \\
 &= 4 \text{ mA}(0.1353) \\
 &= 0.541 \text{ mA} \\
 P_s &= EI_s = (80 \text{ V})(0.541 \text{ mA}) \\
 &= 43.28 \text{ mW}
 \end{aligned}$$

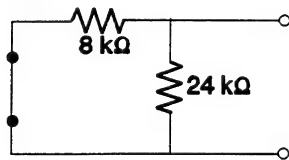
$$\begin{aligned}
 34. \quad a. \quad v_m &= v_R = Ee^{-t/\tau} = 60 \text{ V } e^{-1\tau/\tau} = 60 \text{ V } e^{-1} \\
 &= 60 \text{ V}(0.3679) \\
 &= 22.074 \text{ V}
 \end{aligned}$$

$$\begin{aligned}
 b. \quad i_C &= \frac{E}{R} e^{-t/\tau} = \frac{60 \text{ V}}{10 \text{ M}\Omega} e^{-2\tau/\tau} = 6 \mu\text{A } e^{-2} \\
 &= 6 \mu\text{A}(0.1353) \\
 &= 0.812 \mu\text{A}
 \end{aligned}$$

$$\begin{aligned}
 c. \quad v_C &= E(1 - e^{-t/\tau}) & \tau &= RC = (10 \text{ M}\Omega)(0.2 \mu\text{F}) = 2 \text{ s} \\
 50 \text{ V} &= 60 \text{ V}(1 - e^{-t/2\text{s}}) \\
 0.8333 &= 1 - e^{-t/2\text{s}} \\
 \log_e 0.1667 &= -t/2\text{s} \\
 t &= -(2\text{s})(-1.792) \\
 &= 3.584 \text{ s}
 \end{aligned}$$

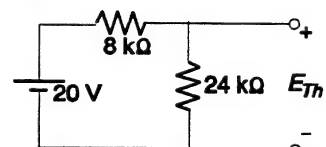
36. a. Thevenin's theorem:

R_{Th} :

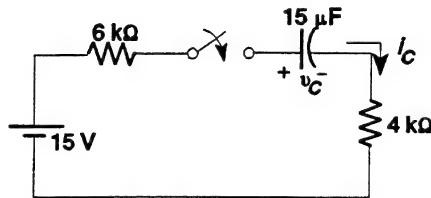


$$\leftarrow R_{Th} = 8 \text{ k}\Omega \parallel 24 \text{ k}\Omega = 6 \text{ k}\Omega$$

E_{Th} :



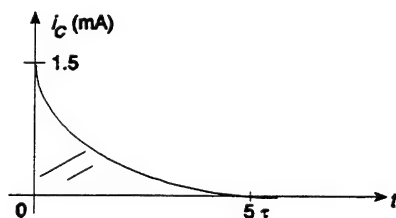
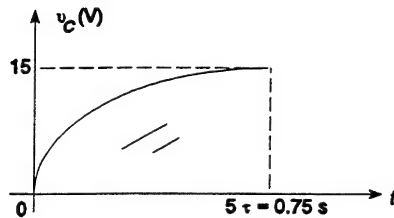
$$E_{Th} = \frac{24 \text{ k}\Omega(20 \text{ V})}{24 \text{ k}\Omega + 8 \text{ k}\Omega} = 15 \text{ V}$$



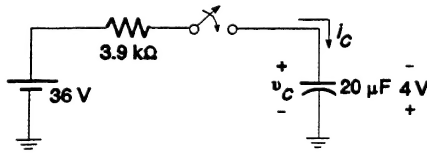
$$\begin{aligned}
 \tau &= RC = (10 \text{ k}\Omega)(15 \mu\text{F}) = 0.15 \text{ s} \\
 v_C &= E(1 - e^{-t/\tau}) \\
 &= 15(1 - e^{-t/0.15})
 \end{aligned}$$

$$i_C = \frac{E}{R} e^{-t/\tau} = \frac{15 \text{ V}}{10 \text{ k}\Omega} e^{-t/0.15} = 1.5 \times 10^{-3} e^{-t/0.15}$$

b.



38. a. $R_{Th} = 3.9 \text{ k}\Omega + 0 \text{ }\Omega \parallel 1.8 \text{ k}\Omega = 3.9 \text{ k}\Omega$
 $E_{Th} = 36 \text{ V}$



$$\tau = RC = (3.9 \text{ k}\Omega)(20 \text{ }\mu\text{F}) = 78 \text{ ms}$$

$$v_C = V_f + (V_i - V_f)e^{-t/\tau}$$

$$= 36 \text{ V} + (-4 \text{ V} - 36 \text{ V})e^{-t/78 \text{ ms}}$$

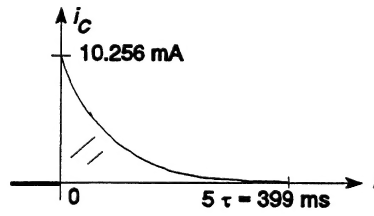
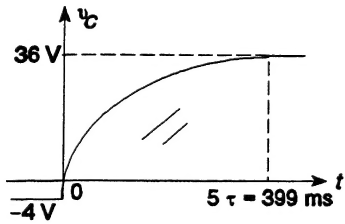
$$v_C = 36 \text{ V} - 40 \text{ V}e^{-t/78 \text{ ms}}$$

$$v_R(0+) = 36 \text{ V} + 4 \text{ V} = 40 \text{ V}$$

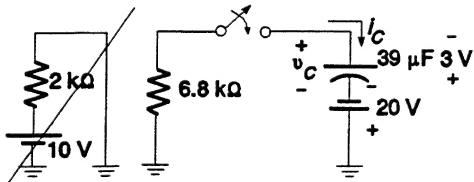
$$i_C = \frac{40 \text{ V}}{3.9 \text{ k}\Omega}e^{-t/78 \text{ ms}}$$

$$i_C = 10.256 \text{ mA}e^{-t/78 \text{ ms}}$$

b.



40. a.



$$\tau = RC = (6.8 \text{ k}\Omega)(39 \text{ }\mu\text{F}) = 265.2 \text{ ms}$$

$$v_C = V_f + (V_i - V_f)e^{-t/\tau}$$

$$= 20 \text{ V} + (3 \text{ V} - 20 \text{ V})e^{-t/265.2 \text{ ms}}$$

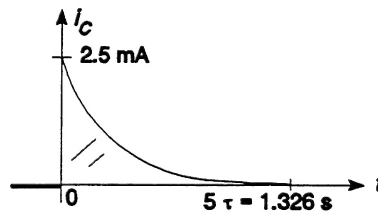
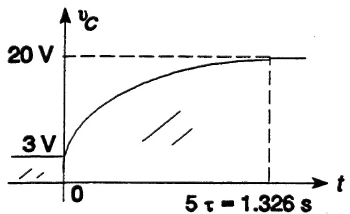
$$v_C = 20 \text{ V} - 17 \text{ V}e^{-t/265.2 \text{ ms}}$$

$$v_R(0+) = 20 \text{ V} - 3 \text{ V} = 17 \text{ V}$$

$$i_C = \frac{17 \text{ V}}{6.8 \text{ k}\Omega}e^{-t/265.2 \text{ ms}}$$

$$i_C = 2.5 \text{ mA}e^{-t/265.2 \text{ ms}}$$

b.



42. $i_C = C \frac{\Delta V}{\Delta t} = 0.06 \times 10^{-6} \frac{\Delta V}{\Delta t}$

$0 \rightarrow 2 \text{ }\mu\text{s}: i_C = 0.06 \times 10^{-6} \left[\frac{3 \text{ V}}{2 \text{ }\mu\text{s}} \right] = 90 \text{ mA}$

$2 \rightarrow 4 \text{ }\mu\text{s}: i_C = -0.06 \times 10^{-6} \left[\frac{6 \text{ V}}{2 \text{ }\mu\text{s}} \right] = -180 \text{ mA}$

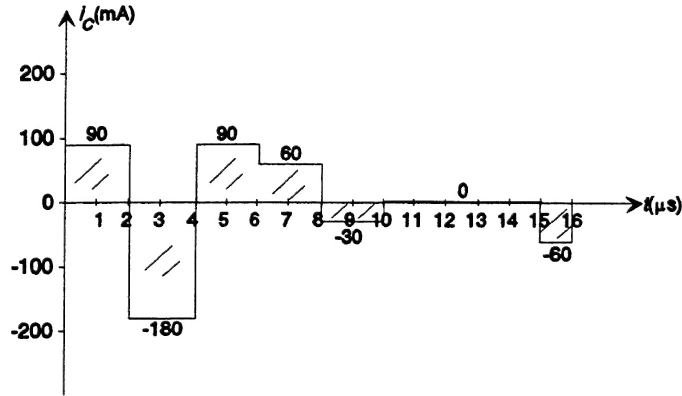
$4 \rightarrow 6 \text{ }\mu\text{s}: i_C = 0.06 \times 10^{-6} \left[\frac{3 \text{ V}}{2 \text{ }\mu\text{s}} \right] = 90 \text{ mA}$

$6 \rightarrow 8 \text{ }\mu\text{s}: i_C = 0.06 \times 10^{-6} \left[\frac{2 \text{ V}}{2 \text{ }\mu\text{s}} \right] = 60 \text{ mA}$

$$8 \rightarrow 10 \mu\text{s}: i_C = -0.06 \times 10^{-6} \left[\frac{1 \text{ V}}{2 \mu\text{s}} \right] = -30 \text{ mA}$$

$$10 \rightarrow 15 \mu\text{s}: i_C = 0 \text{ mA}$$

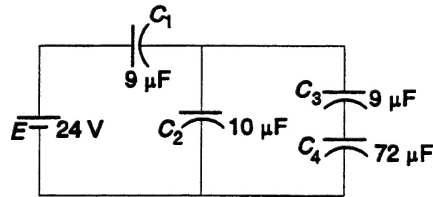
$$15 \rightarrow 16 \mu\text{s}: i_C = -0.06 \times 10^{-6} \left[\frac{1 \text{ V}}{1 \mu\text{s}} \right] = -60 \text{ mA}$$



44. a. $C_T = 0.2 \mu\text{F} \parallel (2 \mu\text{F} + 7 \mu\text{F}) = 0.1957 \mu\text{F}$

b. $C_T = 20 \text{ pF} + 60 \text{ pF} \parallel (10 \text{ pF} + 30 \text{ pF}) = 44 \text{ pF}$

46. a.



$$\frac{(9 \mu\text{F})(72 \mu\text{F})}{9 \mu\text{F} + 72 \mu\text{F}} = 8 \mu\text{F}$$

$$8 \mu\text{F} + 10 \mu\text{F} = 18 \mu\text{F}$$

$$\frac{(9 \mu\text{F})(18 \mu\text{F})}{9 \mu\text{F} + 18 \mu\text{F}} = 6 \mu\text{F}$$

$$C_T = \frac{Q}{V} = \frac{Q}{E} \Rightarrow Q = C_T E = (6 \mu\text{F})(24 \text{ V}) = 144 \mu\text{C}$$

$$Q_1 = 144 \mu\text{C}$$

$$V_1 = \frac{Q_1}{C_1} = \frac{144 \mu\text{C}}{9 \mu\text{F}} = 16 \text{ V}$$

$$V_2 = E - V_1 = 24 \text{ V} - 16 \text{ V} = 8 \text{ V}$$

$$Q_2 = C_2 V_2 = 10 \mu\text{F}(8 \text{ V}) = 80 \mu\text{C}$$

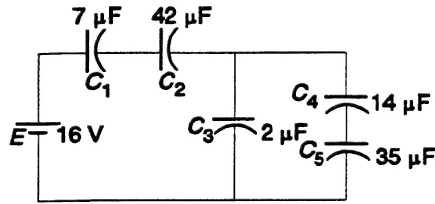
$$Q_{3-4} = C' V = (8 \mu\text{F})(8 \text{ V}) = 64 \mu\text{C}$$

$$Q_3 = Q_4 = 64 \mu\text{C}$$

$$V_3 = \frac{Q_3}{C_3} = \frac{64 \mu\text{C}}{9 \mu\text{F}} = 7.111 \text{ V}$$

$$V_4 = \frac{Q_4}{C_4} = \frac{64 \mu\text{C}}{72 \mu\text{F}} = 0.889 \text{ V}$$

b.



$$\frac{(14 \mu\text{F})(35 \mu\text{F})}{14 \mu\text{F} + 35 \mu\text{F}} = 10 \mu\text{F}$$

$$\frac{2 \mu\text{F} + 10 \mu\text{F}}{2 \mu\text{F} + 10 \mu\text{F}} = 12 \mu\text{F}$$

$$\frac{(7 \mu\text{F})(42 \mu\text{F})}{7 \mu\text{F} + 42 \mu\text{F}} = 6 \mu\text{F}$$

$$C_T = \frac{(6 \mu\text{F})(12 \mu\text{F})}{6 \mu\text{F} + 12 \mu\text{F}} = 4 \mu\text{F}$$

$$Q = CV = (4 \mu\text{F})(16 \text{ V}) = 64 \mu\text{C}$$

$$Q_1 = Q_2 = 64 \mu\text{C}$$

$$V_1 = \frac{Q_1}{C_1} = \frac{64 \mu\text{C}}{7 \mu\text{F}} = 9.143 \text{ V}$$

$$V_2 = \frac{Q_2}{C_2} = \frac{64 \mu\text{C}}{42 \mu\text{F}} = 1.524 \text{ V}$$

$$V_3 = E - V_1 - V_2 = 16 \text{ V} - 9.143 \text{ V} - 1.524 \text{ V} = 5.333 \text{ V}$$

$$Q_3 = C_3 V_3 = (2 \mu\text{F})(5.333 \text{ V}) = 10.667 \mu\text{C}$$

$$Q' = CV = (10 \mu\text{F})(5.333 \text{ V}) = 53.33 \mu\text{C}$$

$$Q_4 = Q_5 = 53.33 \mu\text{C}$$

$$V_4 = \frac{Q_4}{C_4} = \frac{53.33 \mu\text{C}}{14 \mu\text{F}} = 3.809 \text{ V}$$

$$V_5 = \frac{Q_5}{C_5} = \frac{53.33 \mu\text{C}}{35 \mu\text{F}} = 1.524 \text{ V}$$

48. a. $V_{4\text{k}\Omega} = \frac{4 \text{ k}\Omega(48 \text{ V})}{4 \text{ k}\Omega + 2 \text{ k}\Omega} = 32 \text{ V} = V_{0.08\mu\text{F}}$

$$Q_{0.08\mu\text{F}} = (0.08 \mu\text{F})(32 \text{ V}) = 2.56 \mu\text{C}$$

$$V_{0.04\mu\text{F}} = 48 \text{ V}$$

$$Q_{0.04\mu\text{F}} = (0.04 \mu\text{F})(48 \text{ V}) = 1.92 \mu\text{C}$$

b. $V_{6\text{k}\Omega} = \frac{6 \text{ k}\Omega(80 \text{ V})}{6 \text{ k}\Omega + 4 \text{ k}\Omega} = 48 \text{ V} = V_{60\mu\text{F}}$

$$Q_{60\mu\text{F}} = (60 \mu\text{F})(48 \text{ V}) = 2880 \mu\text{C}$$

$$V_{40\mu\text{F}} = 80 \text{ V}$$

$$Q_{40\mu\text{F}} = (40 \mu\text{F})(80 \text{ V}) = 3200 \mu\text{C}$$

50. $W = \frac{Q^2}{2C} \Rightarrow Q = \sqrt{2CW} = \sqrt{2(6 \mu\text{F})(1200 \text{ J})} = 0.12 \text{ C}$

52. a. $V_{6\mu\text{F}} = V_{12\mu\text{F}} = \frac{3 \text{ k}\Omega(24 \text{ V})}{3 \text{ k}\Omega + 6 \text{ k}\Omega} = 8 \text{ V}$

$$W_{6\mu\text{F}} = \frac{1}{2} CV^2 = \frac{1}{2} (6 \mu\text{F})(8 \text{ V})^2 = 0.192 \text{ mJ}$$

$$W_{12\mu\text{F}} = \frac{1}{2} CV^2 = \frac{1}{2} (12 \mu\text{F})(8 \text{ V})^2 = 0.384 \text{ mJ}$$

$$\text{b. } C_T = \frac{(6 \mu\text{F})(12 \mu\text{F})}{6 \mu\text{F} + 12 \mu\text{F}} = 4 \mu\text{F}$$

$$Q_T = C_T V = (4 \mu\text{F})(8 \text{ V}) = 32 \mu\text{C}$$

$$Q_{6\mu\text{F}} = Q_{12\mu\text{F}} = 32 \mu\text{C}$$

$$V_{6\mu\text{F}} = \frac{Q}{C} = \frac{32 \mu\text{C}}{6 \mu\text{F}} = 5.333 \text{ V}$$

$$V_{12\mu\text{F}} = \frac{Q}{C} = \frac{32 \mu\text{C}}{12 \mu\text{F}} = 2.667 \text{ V}$$

$$W_{6\mu\text{F}} = \frac{1}{2} CV^2 = \frac{1}{2} (6 \mu\text{F})(5.333 \text{ V})^2 = 85.32 \mu\text{J}$$

$$W_{12\mu\text{F}} = \frac{1}{2} CV^2 = \frac{1}{2} (12 \mu\text{F})(2.667 \text{ V})^2 = 42.68 \mu\text{J}$$